Naval Surface Warfare Center
Carderock Division
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NSWCCD-CISD–2008/010 July 2008

Ship Systems Integration & Design Directorate

Technical Report

Littoral Reconnaissance Ship

by

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Unrestricted Distribution

NSWCCD-CISD-2008/010

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
08-Aug-2008

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
19-May-2008 – 08-Aug-2008

4. TITLE AND SUBTITLE
Littoral Reconnaissance Ship

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Abrell, Scarlet and Sajban, Andrew

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center
Carderock Division
9500 Macarthur Boulevard
West Bethesda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER
NSWCCD-CISD-2008-010

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Chief of Naval Research
One Liberty Center
875 North Randolph Street,
Suite 1425
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Unrestricted Distribution/ Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Unmanned Vehicles are increasingly becoming an important factor in US naval operations. UVs can provide the reconnaissance data needed for fleet operations without endangering personnel. However, the capabilities of the UVs are somewhat limited because of the lack of their own designated support group. It is not desirable to use an expensive multirole surface combatant for a single mission focus. In order to fully utilize the capabilities of these UVs, a ship that can fully support them, independent of the existing fleet, should be considered.

In order to meet this need for dedicated support for UVs the Littoral Reconnaissance Ship was designed. The LRS provides all of the capabilities needed for unmanned vehicles to be launched, recovered, and maintained while at sea. When the LRS is fully equipped it can provide continuous unmanned vehicle reconnaissance to the fleet.

15. SUBJECT TERMS
Littoral Reconnaissance Ship, Unmanned Vehicle Support Ship, SWATH, UAV, USV, UUV

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL	36	Colen Kennell 301-227-5468

Abstract

Unmanned Vehicles are increasingly becoming an important factor in US naval operations. UVs can provide the reconnaissance data needed for fleet operations without endangering personnel. However, the capabilities of the UVs are somewhat limited because of the lack of their own designated support group. It is not desirable to use an expensive multirole surface combatant for a single mission focus. In order to fully utilize the capabilities of these UVs, a ship that can fully support them, independent of the existing fleet, should be considered.

In order to meet this need for dedicated support for UVs the Littoral Reconnaissance Ship was designed. The LRS provides all of the capabilities needed for unmanned vehicles to be launched, recovered, and maintained while at sea. When the LRS is fully equipped it can provide continuous unmanned vehicle reconnaissance to the fleet.

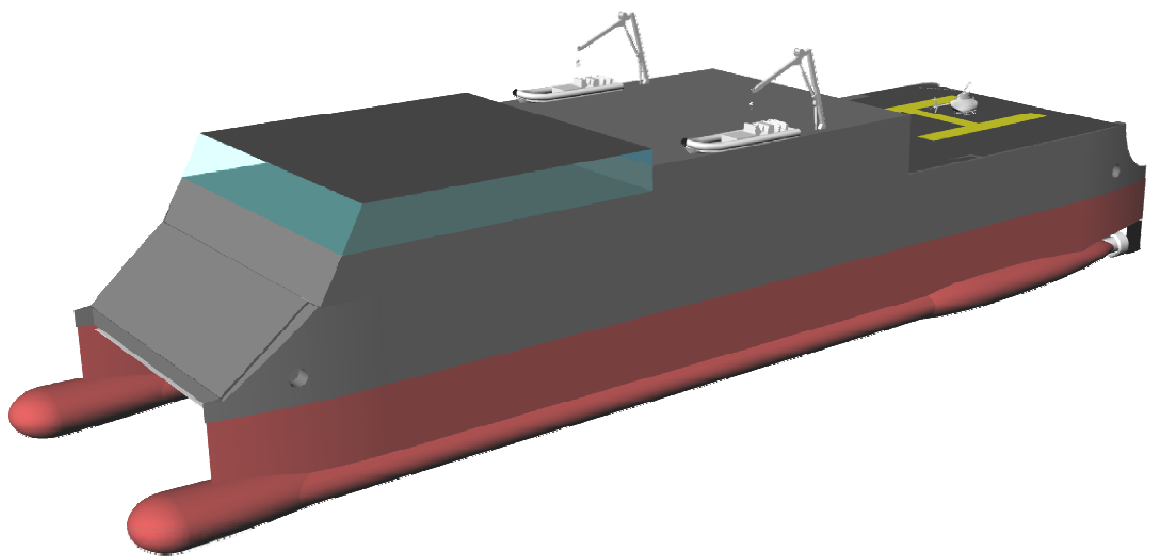


Table of Contents

List of Figures

List of Tables

Executive Summary

As unmanned vehicles are being introduced to the fleet in larger numbers and with greater mission capabilities, it is becoming apparent that a versatile, inexpensive platform devoted to their launch and recovery is required to support them effectively. In response to this need, a Littoral Reconnaissance Ship (LRS) has been developed to provide a platform for unmanned vehicles. The LRS is a Small Waterplane Area Twin Hull (SWATH) ship which deploys Unmanned Aerial Vehicles (UAV), Unmanned Surface Vehicles (USV), and Unmanned Underwater Vehicles (UUV). With the use of these unmanned systems, the LRS can support a broad range of tasks including Intelligence, Surveillance, and Reconnaissance (ISR), Mine Warfare (MIW), Anti Submarine Warfare (ASW), Surface Warfare (SUW), and Strike Warfare. Due to its varied capabilities this vessel can directly provide support to the fleet by being integrated into strike groups or by acting independently. This makes the LRS a versatile vessel which can be employed into nearly any type of naval operation.

The LRS is unique when compared to other ships in operation today. It utilizes the High Speed Sea Lift (HSSL) SWATH hull form which provides good stability and seakeeping characteristics in a small hull. It is also unique in that the main power is supplied by 18 fuel cells, which are currently being developed by ONR. Unlike most ships, which use cranes and ramp systems to recover craft, the LRS uses a lift located between its demi-hulls to lower and raise UUVs and USVs to and from the water.

1 Introduction

1.1 LRS Design Team

The LRS Team is a group of three interns under the direction of the CISD permanent staff. The group includes:

Name	School	Degree
Scarlett Abrell	Virginia Tech	Ocean Engineering
Andrew Adelsen	United States Naval Academy	Naval Architecture
Andrew Sajban	Florida Atlantic University	Ocean Engineering

The interns worked under the Naval Research Enterprise Intern Program (NREIP), funded by the Office of Naval Research (ONR). The team is based at the Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center, Carderock Division (NSWCCD). The LRS team spent ten weeks designing a ship to meet the stated LRS requirements. Andrew Adelsen worked on the initial investigation of the unmanned vehicles used in the Navy today, but had to leave for personal business prior to the midterm reviews. Andrew Sajban and Scarlett Abrell carried the project to completion. The following report illustrates the team's concept design and findings with respect to the Littoral Reconnaissance Ship.

1.2 Mission Statement

The Littoral Reconnaissance Ship (LRS) team had the task of designing a host ship for operating unmanned aerial, surface, and sub-surface vehicles. The LRS was required to be capable of launching, recovering, refueling, controlling, and maintaining unmanned vehicles while at sea. The unmanned air vehicles need to provide 12 hours of daily reconnaissance, while the unmanned surface and subsurface vehicles need to provide six hours of reconnaissance per day in each of their respective domains. The unmanned vehicles can be maintained, refueled, and outfitted with different mission packages on the ship, then launched again to continue the mission.

1.2.1 LRS Requirements

The following is a list of requirements for the LRS (Better detailed in Appendix C):

1. Capable of independent intra-theatre operations, 1000 Nm away from the support provided by an intermediate support base.
2. The vessel, each day, shall provide reconnaissance using unmanned vehicles in the following domains:
    a. Air: 12 hours
    b. Surface: 6 hours
    c. Subsurface: 6 hours

3. All unmanned vehicles must be launched, recovered, refueled, and repaired onboard the LRS.
4. LRS will operate in a sprint and drift manner, traversing between reconnaissance locations at the designed cruise speed, and then loitering at low speed while operating the unmanned vehicles.
5. The vessel shall be capable of defending itself against attacks by hostile patrol craft.

2 Mission

2.1 Concept of Operations

The concept of operations for the LRS was the main driving factor in the design of the ship. The LRS was designed to perform the worst case scenario. It has the ability to travel 1000 nm at full speed to a point of interest without support. The LRS has the capability and speed to launch eight unmanned underwater vehicles in a potential threat area and then return to a safe zone while the UUVs perform their missions. The LRS has the ability to collect the first group of UUVs and replace them all for further surveillance. The UUVs travel at a very slow speed (3 knots), and therefore need to be launched and recovered close to the target area for surveillance. If eight UUVs are simultaneously operated, they can survey a total area of 64 square miles in 18 hours. The USVs and UAVs have a greater range and speed and can be operated at distances from the ship, allowing them to return to the ship at the end of the mission. Depending upon the total duration of the mission the LRS can be refueled at a nearby port or it can return to its home port within a 1000 nm range.

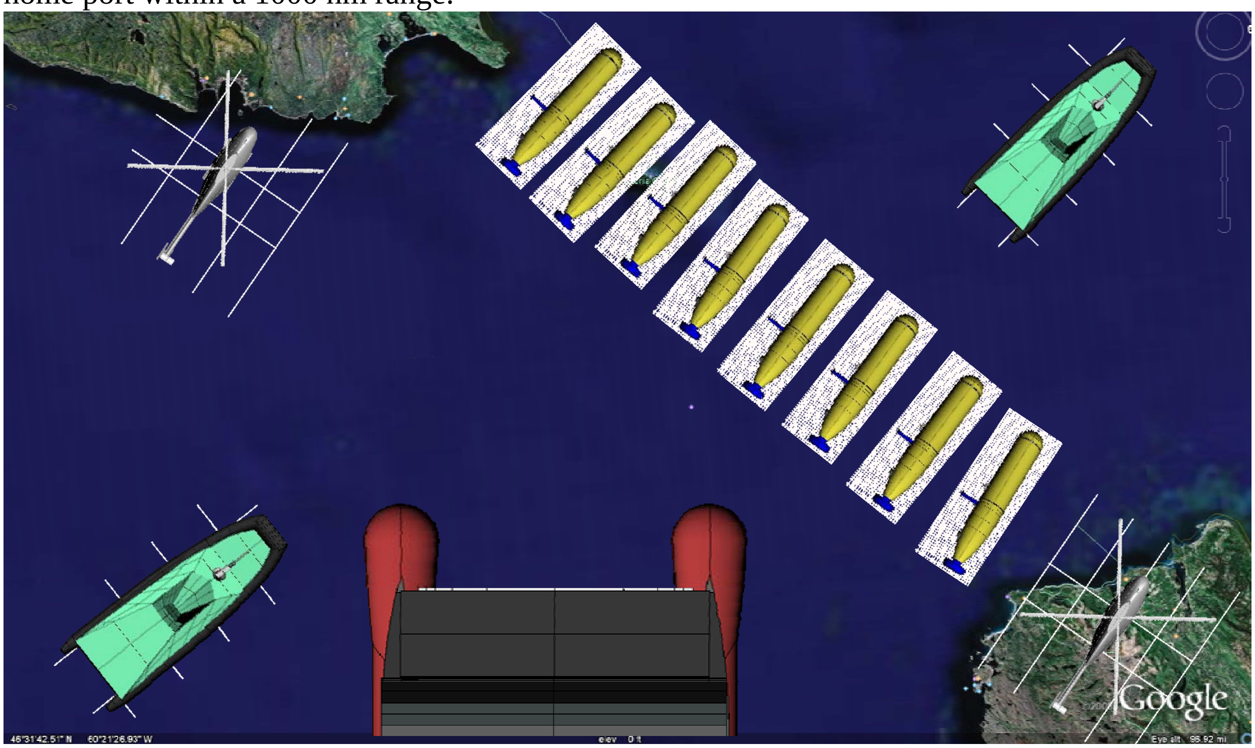


Figure 1: Concept of Operations

2.2 Selection of UVs

2.2.1 Unmanned Aerial Vehicles

The cargo to be carried includes three types of unmanned vehicles; air, surface, and subsurface. Some of the different types of aerial unmanned vehicles include vertical takeoff, pneumatic launch, and hand launch. The LRS is equipped with vertical takeoff UAVs for two main reasons. For pneumatic and catapult launch, the runway length required for takeoff and landing significantly increased the length of the LRS. Also, the handheld UAVs did not provide the mission capabilities needed, therefore the Fire Scout was chosen.

The LRS is capable of carrying up to four Fire Scouts with enough fuel and supplies to operate for one month. With a dual operating system for control, two Fire Scouts can conduct missions simultaneously while the other two are repaired, refitted, and refueled. The Fire Scout UAV has the capability of providing the required twelve hours of flight time without refueling. The Fire Scout UAV was chosen as the primary UAV aboard the LRS due to its wide array of sensor packages, multi-mission capability, availability, and ease of handling and launching. Some of the Fire Scout Missions include:

- Intelligence, Surveillance, and Reconnaissance (ISR) – provide intelligence through infrared cameras, communication relays, and electro-optic sensors.
- Anti Submarine Warfare (ASW) – detect submarines using sonar buoys and prosecute using a lightweight torpedo
- Mine Warfare (MIW) – detect mines using a magnetic anomaly detector
- Surface Warfare (SUW) – engage surface targets using Hellfire missiles, Hydra Rockets, Viper strike weapons, and numerous others
- Strike Warfare – Can engage targets using same weapons systems used in SUW and can provide targeting data to other units using visual data and an onboard laser rangefinder/designator

Figure 2: Fire Scout UAV

2.2.2 Unmanned Surface Vehicles

There are currently four different types of unmanned surface vehicles which include the X-Class, Harbor Class, Snorkeler Class, and Fleet Class. The Harbor Class is the most widely used in the navy today and has a sufficient payload and operating time for the requirements. The LRS can carry two Harbor class USVs which measure seven meters in length. These USVs are stored in cradles where they can undergo routine maintenance including sensor and weapon package switch out. To launch these boats, an overhead gantry crane will be utilized to transfer the USVs from their cradles to the lift. The lift then lowers the USVs into the water. The reverse process will be utilized to recover the USVs. The USVs missions include:

- Intelligence, Surveillance, and Reconnaissance (ISR) – provide intelligence through infrared cameras, communication relays, and electro-optic sensors.
- Anti Submarine Warfare (ASW) – detect submarines using sonar buoys and prosecute using a lightweight torpedo
- Mine Counter Measures (MCM) – delivery, search, and neutralization of mines
- Maritime Security (MS) – prevention of international damage through sabotage, subversion, or terrorism
- Surface Warfare (SUW) – engage targets using a variety of weapons

Figure 3: Protector USV

2.2.3 Unmanned Underwater Vehicles

There are four types of unmanned underwater vehicles. They include the Man-Portable Class, Light Weight Vehicle Class, Heavy Weight Vehicles Class, and Large Vehicle Class. The LRS uses the Heavy Weight Vehicle class because of its unique combination of adequate size and effective mission capabilities. The LRS can carry 16 UUVs. These UUVs will be stored in "torpedo" storage racks. From these racks, the UUVs will be launched by being moved through the same gantry crane as the USVs and transferred to the lift system to lower the UUV into the water. They will be recovered by the lift and put back into the racks using the gantry crane. The UUVs' missions include:

- Intelligence, Surveillance, and Reconnaissance (ISR)
- Mine Warfare (MIW) –detect mines using a magnetic anomaly detector
- Geographic Surveillance
- Information Operations (IO) –provide submarine decoy

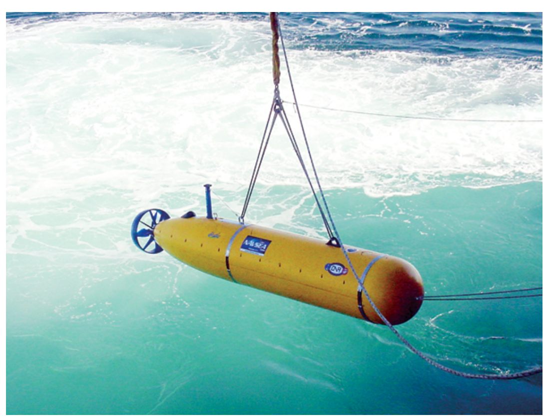


Figure 4: Bluefin 21 UUV

The UVs chosen for the LRS provide sufficient reconnaissance for aerial, surface, and subsurface missions. The constant surveillance provided by the UVs enhances the mission capabilities of the LRS in a threat area.

3 Ship Design and Engineering

3.1 Introduction to the HSSL SWATH Hull Form

The design criteria specified the use of the High Speed Sea Lift (HSSL) SWATH hull form. The HSSL SWATH was developed as a hullform that has the good seakeeping characteristics of typical SWATHs with the benefit of better resistance properties than most other SWATH hullforms of similar size.[1] Models of the hull were previously built and tested at the United States Naval Academy and NSWCCD. A SWATH design, or Small Waterplane Area Twin Hull, provides improved seakeeping over a monohull design because most of the hull volume is below the surface of the water and thus less affected by waves. SWATH ships have two demi-hulls that are fully submerged and relatively narrow struts with minimal waterplane area that connect the demi-hulls to the main cross-structure. This cross-structure provides a large area for deckspace, which helps to accommodate the unmanned vehicles. LRS uses a scaled version of this hull form due to these desired advantages that the HSSL SWATH hullform has over other hullforms.

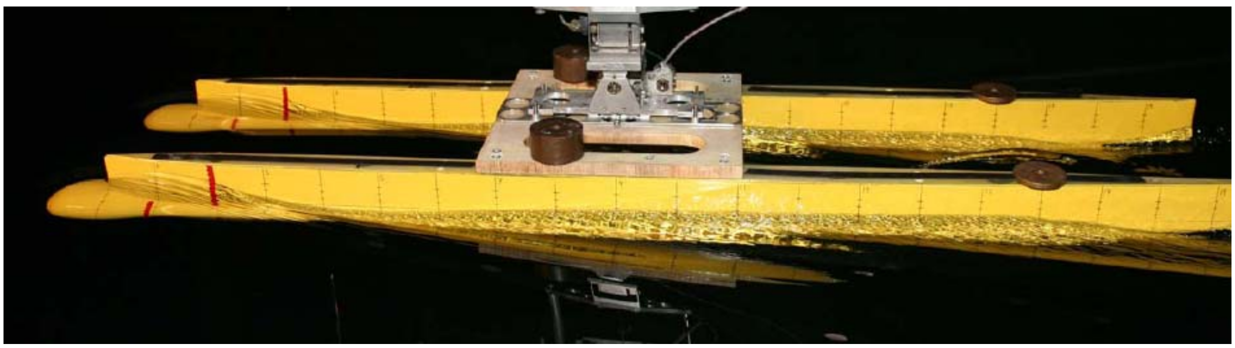


Figure 5: HSSL SWATH model test

3.2 Design Features

The LRS has certain characteristics that set it aside from other ships its size. Its main mission is to launch, recover, and maintain UVs. The LRS was designed with an aluminum structure to reduce weight and provide less corrosion prevention maintenance. Other features include a large flight deck and mission bay. The fully integrated electric system, powered by fuel cells, provides the ship with sufficient power and efficiency while being environmentally friendly.

Table 1: LRS Principal Characteristics

Displacement (mt):	1,145.5 full load
Length(m):	73
Beam (m):	16
Draft (m):	3.5
Max Speed, knots:	25
Hull Material:	Aluminum
Installed Power	9 MW
Complement:	63
Total Fuel Storage (mt):	190
Machinery:	18 Fuel Cells 2 ABB Electric Motors 2 Pumpjets
Payload:	(4) UAVs, (2) USVs, (16) UUVs, (2) 7m RHIBs

3.2.1 UAV Flight Deck and Hangar Bay

The flight deck, which is used to launch the Fire Scout, is 14 x 14 meters. This area was considered adequate based on the size of the UAV, but has yet to be approved by NAVAIR. The hangar bay can stow all four of the Fire Scouts and their associated equipment and missions packages. All items necessary to operate the four Fire Scouts are stored in three standard twenty foot containers (TEU).

3.2.2 USV and UUV Mission Bay

The unmanned surface and subsurface vehicles are located on the third deck forward of the lift. Each USV is stored in a cradle oriented longitudinally along the centerline of the LRS with one cradle immediately forward of the other. The cradles can be moved around the deck of the ship using the overhead gantry crane. When the LRS reaches its offload point, the USVs will be picked up with the gantry crane and transferred to the lift to be launched. The UUVs will be stored alongside the USVs, and will be moved with the aforementioned gantry crane. After the unmanned vehicles have completed their missions and are recovered by the lift, the gantry crane will return them to their cradles.

3.2.3 Lift

One of the key features for launch and recovery of UUVs and USVs aboard the LRS is the lift and cradle. The cradle is based on a concept by "Surface Combatant Optimized for Unmanned Vehicle Operations" (SCOUVO) [7]. There are some differences from the SCOUVO cradle design when it is incorporated onto the LRS. One of these differences is that the cradle will be situated on a lift rather than a stern ramp. This will require minor changes to the cradle design. The cradle will be secured to a hydraulic lift

platform that has the ability to travel from the third deck to below the waterline. The lift will be raised and lowered by six large hydraulic pistons (three port and three starboard) with the fore and aft ends of the lift unobstructed. The area for the lift is 13x5 meters with an overhead height of 5 meters. The hydraulic lift platform will be controlled on the third deck via a control center while the ship is at zero speed.

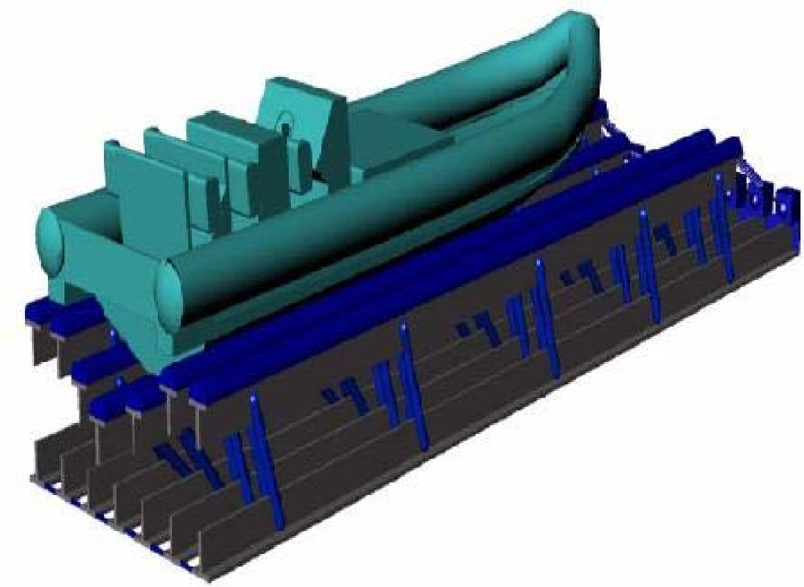


Figure 6: SCOUVO Cradle

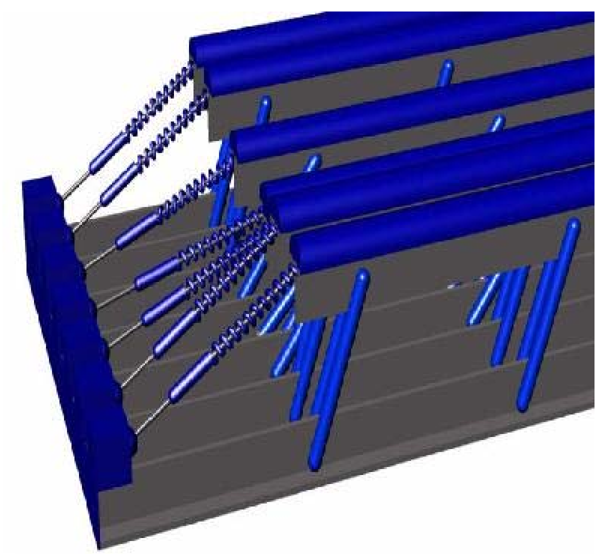


Figure 7: Front View of SCOUVO Cradle

3.2.4 Launch and Recovery

Once an unmanned vehicle is on the cradle, the lift operator can lower the lift to the water. The vehicles can then deploy from the cradle in a variety of methods. Some vehicles will slide off of the lift as the ship is moving forward at very low speeds. Some of the UVs can be remotely operated, and some can be programmed to move once in the water. The recovery of the UVs will differ depending upon the type. The USVs will be guided to the cradle via GPS or another guidance system. The UUVs will use a beacon that is attached to the lift to guide it to the cradle or they will be remotely controlled. Once the unmanned vehicles are returned to the mission bay they can be attached to a hoist and moved to their appropriate area.

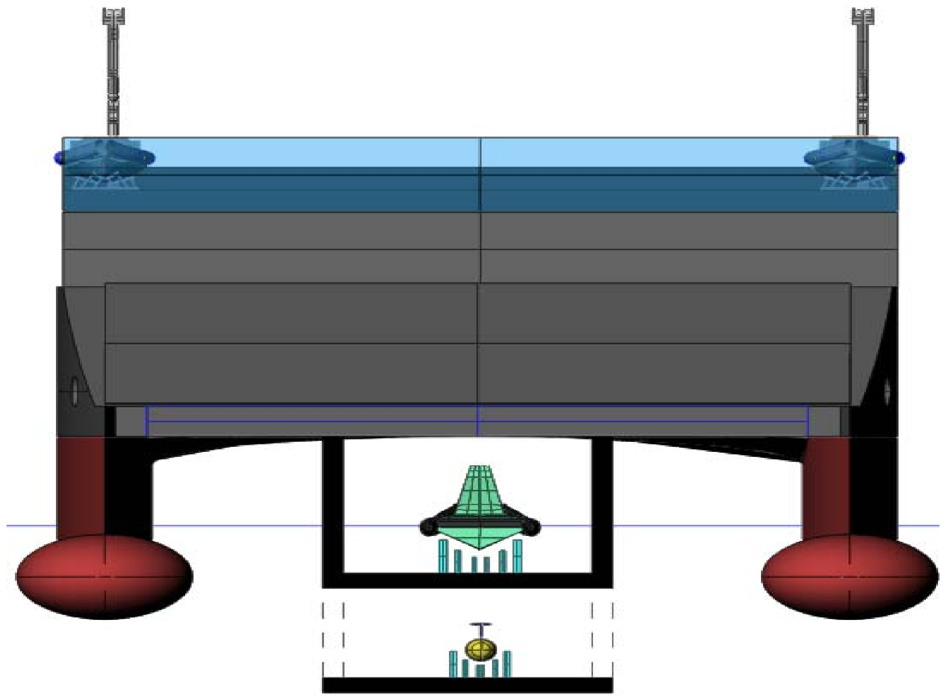


Figure 8: Front View of the LRS with Lift Lowered for Surface and Submerged Models

3.2.5 Defense System and Counter Measures

The launch and recovery of UV's aboard the Littoral Reconnaissance Ship will be conducted in an operational area and a defense capability is required. The LRS is equipped with two Phalanx Block 1B CIWS pods located forward and aft to provide a full range of protection from Anti-Ship Cruise Missile (ASCM), helicopter, air, and surface threats. Some of the advantages with the Block 1B model are the wider variety of threats it is able to detect and destroy as well as its range. The Phalanx does not require a large crew to operate; only three technicians are needed. The threats that the CIWS can provide protection against in a littoral threat zone can be seen in Figure 10.

Figure 9: Phalanx CIWS

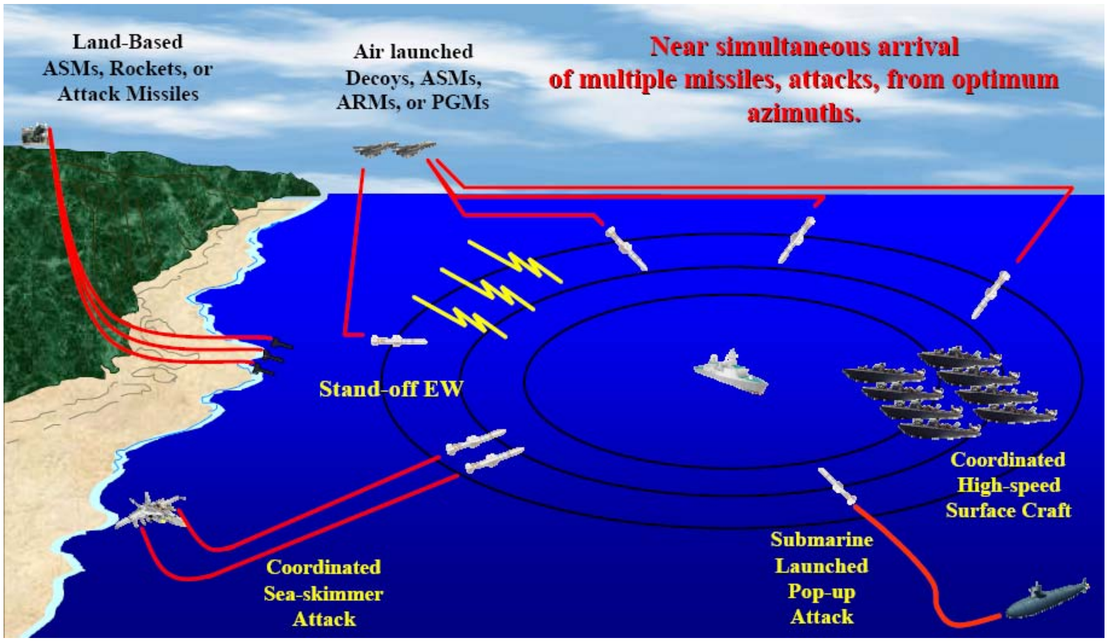


Figure 10: Littoral Threat

A countermeasure system is required and the MK 36 Super Rapid Bloom Offboard Countermeasures (SRBOC) was chosen. The SRBOC is a tube launching

system for chaff and decoys against a variety of threats, includeing anti-ship missiles. The SRBOC is a radar countermeasure system that ejects either foil or a group of thin wires into the air so that the radar waves that a radar guided missile is controlled by are disrupted and confused.

Figure 11: SRBOC

3.3 Electrical Power Generation and Propulsion

The Littoral Reconnaissance Ship is an all-electric ship with all power generation supplied by a PEM Fuel Cell System. The basic unit of this fuel cell system is being developed by the Office of Naval Research[12] and should be introduced to the fleet by 2018. Each fuel cell module (2.4 x 1.5 x 2.4 m) consists of a fuel reformer and fuel cell stack and provides 500 kW of power. Either DFM-76 or JP-5 will fuel the system depending on the reformer sub-system ONR chooses to develop. The fuel cell system will consist of eighteen 500 kW modules split equally between starboard and port on the ship for a total of 9 MW of power generation. On both sides, nine modules will be linked by a common desulfurizer prior to power generation (for preliminary fuel purification) and a converter after power generation (for combination and conversion of the generated DC power to AC power for ship use).

The all-fuel cell system implemented in this design offers greater advantages over other near-future naval propulsion systems for an LRS type ship. An analysis of power systems by power density, volumetric and gravimetric density, and operational costs illustrates the advantage of an all-fuel cell propulsion system.

Power efficiency of the fuel cells will be at least 40%[12]. Current performance at 50% load is 40% but efficiency is likely to improve by the time the system is deployed[12]. Volumetric and gravimetric densities for the LRS fuel cell system are already much better than those of first generation fuel cell systems developed by the Navy. While some conventional systems are lighter, given the positive tradeoffs of fuel cells this weight is not a substantial problem. Further, as reforming techniques improve in the coming years, the weight of the fuell cells will likely decrease. In comparison to conventional

mechanical propulsion systems, the fuel cell is much more space efficient because electric power is directly generated. The system runs on standard Navy fuels and the amount of fuel required to operate a fuel cell is low compared to diesel engines or gas turbines[12] of comparable power outputs. Also, since fuels cells have relatively simple designs and few moving parts, the manpower requirements for maintenance and repair will also be less than comparable methods of mechanical power generation.

Further advantages of fuel cell systems include environmental and tactical. Fuel cells are more environmentally friendly in the immediate sense as the only byproducts of the system are oxygen and water. Tactically, the reduced noise and heat of the system improves the acoustic and thermal signature of the ship, which is advantageous in the littoral environment. Furthermore, the survivability of the ship is improved due to the distribution of the power source across both sides of the ship.

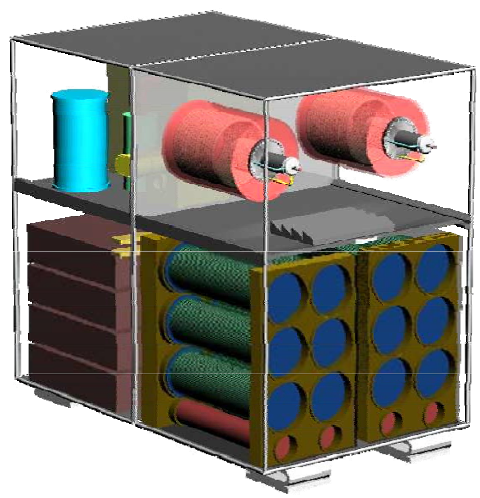


Figure 12: 500 kW ONR Fuel Cell Concept

3.4 Electric Motor

The LRS's main power is generated from multiple fuel cells. The power is then distributed to switchboards that will designate an amount for the ship's services and propulsion, which is represented in Figure 13. With total power onboard the LRS at 9 MW and an estimated ship's services load at 1.5 MW, the power supplied to propulsion would be an estimate of 7.5MW. With this estimate the LRS needs two electric motors for propulsion, one located in the port demi-hull and one in the starboard demi-hull, each rated at 4 MW. The ABB Group was chosen as the manufacturer of the LRS's electric motors.

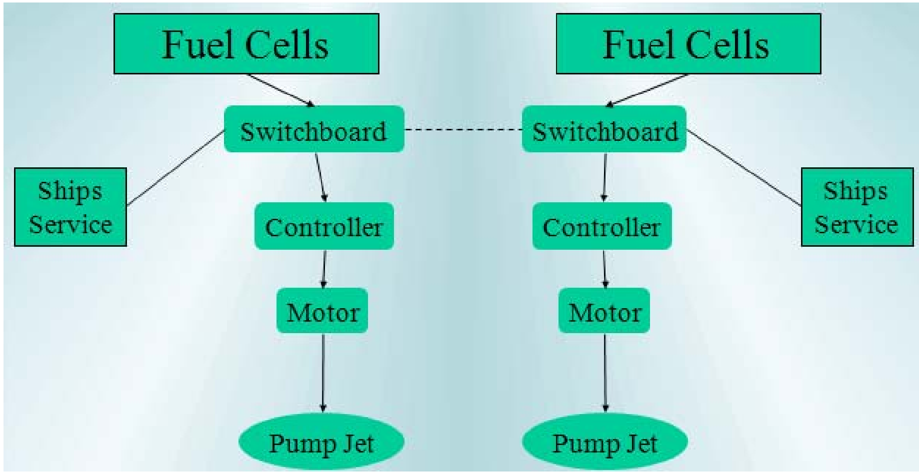


Figure 13: LRS Electrical Distribution Schematic

3.5 Propulsion

The propulsion system chosen for the LRS was the pump jet. The pump jet provides advantages and disadvantages to the LRS. One of the advantages is that the propeller is shielded by the surrounding duct structure. This is essential for the LRS because of the unmanned underwater and surface vehicles that will be in the water in the general area of where a propeller would be, and if contact between these were to occur then damage to both the unmanned vehicles and the LRS could be significant. Also, since the LRS will be operating in a littoral area where a shallower draft will provide an advantage, the pump jet is will have an impeller of a smaller diameter than a comparable conventional marine propeller. One of the disadvantages to the use of the pump jet is its propulsion coefficient throughout the speed range. The efficiency of the pump jet is comparable or better than a standard propeller system at higher speeds, but much less at lower speeds. Due to this characteristic, other pump jet technology has been studied.

3.5.1 Counter-rotating Pump Jet

A new pump jet technology is the counter-rotating pump jet. The technology was developed and is being employed by the boat racing community. The counter-rotating pump jet delivers many advantages over a conventional pump jet. One of the main advantages and also the reason for it being considered aboard the LRS is that it provides a much better overall propulsion coefficient (PC) throughout the speed range. Preliminary tests showed that the PC was comparable to that of a conventional marine propeller system[3]. Also, the counter-rotating impellers have a higher efficiency than standard pump jets because they operate at half the speed. Also with the impellers counter-rotating nearly all the rotational energy caused by swirl is recovered by the second impeller. The dual impellers may also prove to be more durable. The downside to this technology is that it is new and thus inherently viewed as a technical risk.

It should be noted that there is very little information about pump jets publicly available since their application has been limited mostly to submarines and torpedoes.

However, since the impeller of a pump jet is similar in design and operates on the same principles as waterjets, conservative estimates were made using prediction tools developed for waterjets and deemed adequate for this conceptual work. Figure 14 shows a waterjet fitted with counter-rotating impellers. Based on the powering estimates for the hullform and a desired speed of 25 knots, it was predicted that the LRS will require dual pump jets weighing 3.87 metric tons each with impeller diameters of 0.71 meters.

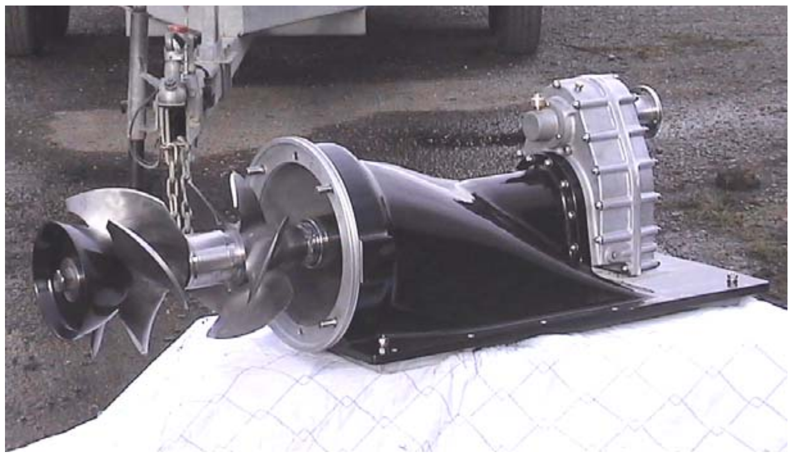


Figure 14: Counter-rotating Waterjet

3.6 Powering Estimates

To determine the amount of power needed aboard the ship, HSSL hull model data was scaled to the LRS's characteristics using an assumed propulsive coefficient of 0.7. Figure 15 shows the amount of power required to achieve a desired speed for the LRS. With the LRS's powering requirement determined, an endurance database was generated. Using the LRSs characteristics and fuel capacity, a table was created to determine its endurance shown in Figure 16.

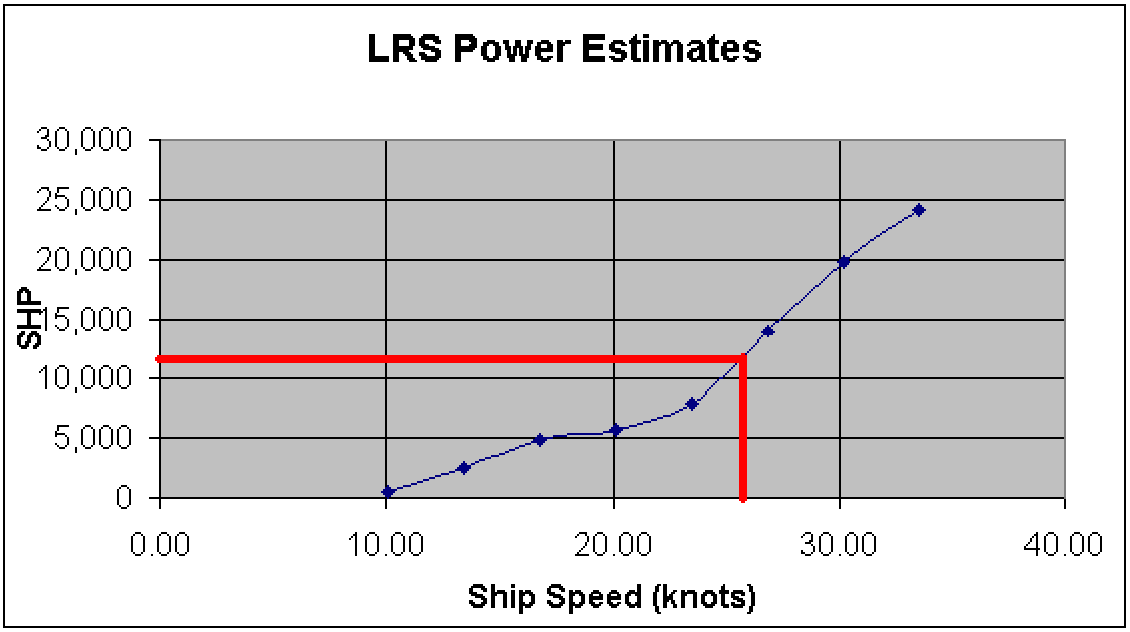


Figure 15: LRS Power to Speed Curve

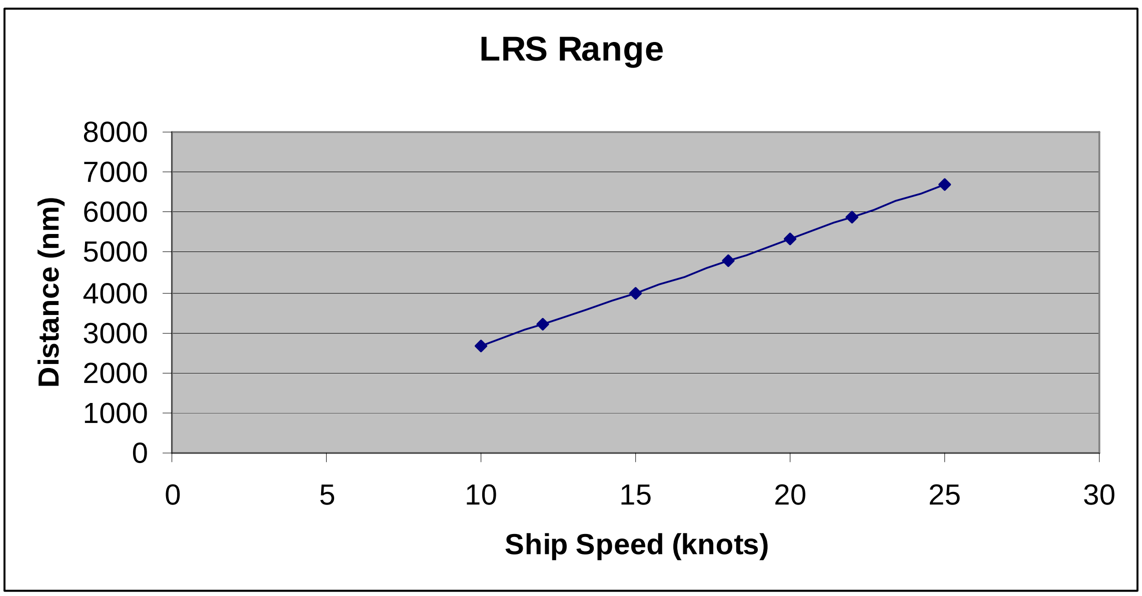


Figure 16: Distance to Speed Curve

3.7 General Arrangements

The LRS design architecture was defined by the numerous unmanned vehicles onboard. After determining the minimum space needed for storage and other requirements, a database was constructed to scale the superstructure. The scaling of the HSSL hull form was then linked to the LRS weights spreadsheet. As the weight increased or decreased, the overall size of the ship changed. When the dimensions were finalized the architectural arrangements on the LRS were adjusted to accommodate the necessary

equipment and working spaces. The decks' general spaces include the bridge and flight operations controls on the 01 deck. The main deck consists of the flight deck and hanger bay with mission and habitability spaces near the bow. The second deck consists of the main habitability spaces near the bow and some mission spaces aft. The third deck contains the mission bay, lift, switchboards, fuel cells, galley, mess, and various other machinery and mission spaces. The lower decks house more machinery spaces and motor rooms, while tanks for fuel, water, and other liquids are in both hulls. (See Appendix A for general arrangements)

3.8 Weight Estimation

The overall size of the LRS was determined using a comprehensive Ship Weight Breakdown Structure (SWBS) weight estimate. Weights for each of the SWBS categories listed below were entered into a database and an estimated ship size was determined. It was an iterative process, to develop a weight and ship size to ensure we had enough power and fuel to achieve the speed, range, and meet all other design constraints. The final displacement was 1,145 metric tons.

3.8.1 SWBS 100 – Hull Structures

The 100 group of the SWBS contains estimates for the weights of all structural components. Group 100 of the LRS was calculated using an average structural density of 2 pounds per cubic foot, the structural density of aluminum[9]. The total for the 100 group is 351.5 metric tons.

3.8.2 SWBS 200 – Propulsion Plant

The 200 group contains weights for all propulsion equipment. Most of our weight in this category is from the fuel cells. Specific weights for the fuel cells were used, but the other sub-categories within group 200 were obtained from scaling X-Craft data[11].

3.8.3 SWBS 300 – 700

Groups 300 through 700 include the electric plant, command and control, auxiliary systems, outfit and furnishings, and armament. These groups were scaled from the X-Craft[11].

3.8.4 Summary of Weight Estimates

The overall lightship weight of the LRS is 880 metric tons including a 15% margin. A 15% margin was used due to the inherent uncertainty associated with the scaling of data from a number of the weight groups from existing ships. Including the weight of fuel the full load displacement became 1145.5 metric tons.

Table 2: SWBS Weight Estimate

SWBS	Group	Weight (mt)
100	Hull Structures	351.5
200	Propulsion Plant	146
300	Electric Plant	30.5
400	Command & Control	10
500	Auxiliary Systems	162.5
600	Outfit & Furnishings	51
700	Armament	13.5
	Lightship	765
	Lightship + Margin	**880**
800	Deadweight	265.5
	Full Load	**1145.5**

3.9 Stability Assessment

Bulkheads were placed in the LRS so that it would meet the two compartment survivability standards set forth by the Navy. The time available did not permit for analysis to be done to verify compliance with the damaged stability standards. This area should be developed for future work.

The calculated loaded GM is 8.9 meters and the unloaded GM is 7.8 meters. The unloaded GM was calculated with no fuel onboard and all of the unmanned vehicles deployed. With a positive unloaded GM there is no need for a ballast system. The GM of the loaded and unloaded ship is high for a ship only displacing 1,145.5 metric tons. Experiments have been undertaken on the HSSL hull model[1], which also has a similarly high GM, but good sea keeping characteristics.

Table 3: Stability Characteristics

	Loaded	Unloaded
KG	6.9 m	7.9 m
KB	1.7 m	1.7 m
BM	14 m	14 m
GM	8.9 m	7.8 m

4 Conclusion

4.1 Project Summary

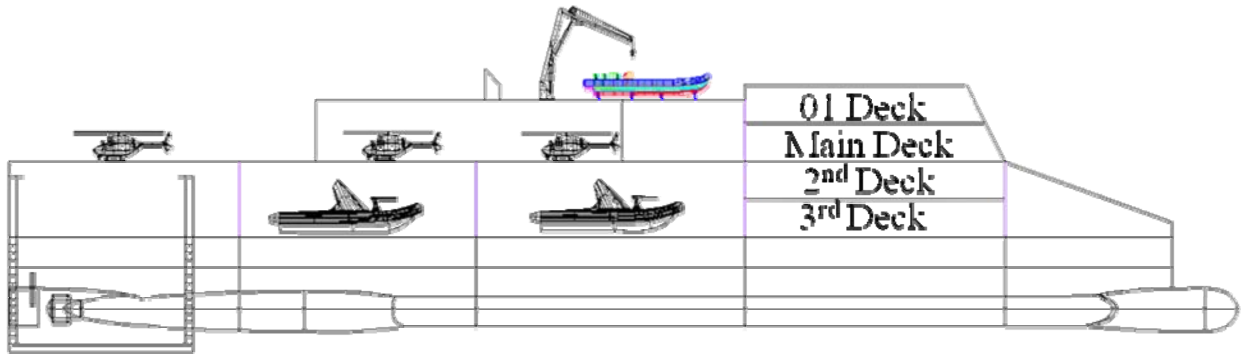
The Littoral Reconnaissance Ship presented in this report represents a concept that could help solve a capability gap for the United States Navy. The use of more unmanned vehicles in the fleet is a realization that the current Navy is not equipped to handle practically. With the LRS, the ability to transport, store, launch, recover, maintain, and refuel unmanned aerial, surface, and subsurface vehicles is possible in a single dedicated vessel. The LRS also incorporates many cutting edge technologies such as the use of ONRs 500kW fuel cell and counter-rotating pump jets. The High Speed Sea Lift (HSSL) SWATH hullform has been tested and gives evidence of improved seakeeping and stability. The LRS also has other key features, for example the endurance of 2,000 nm at a top speed of 25 knots, or 4,000 nm at 15 knots. In conclusion the LRS team has presented a concept that fits the requirements for a ship whose main purpose is the launch, recovery, and maintenance of unmanned vehicles used by the Navy of today and the future.

4.2 Recommendations for Future Work

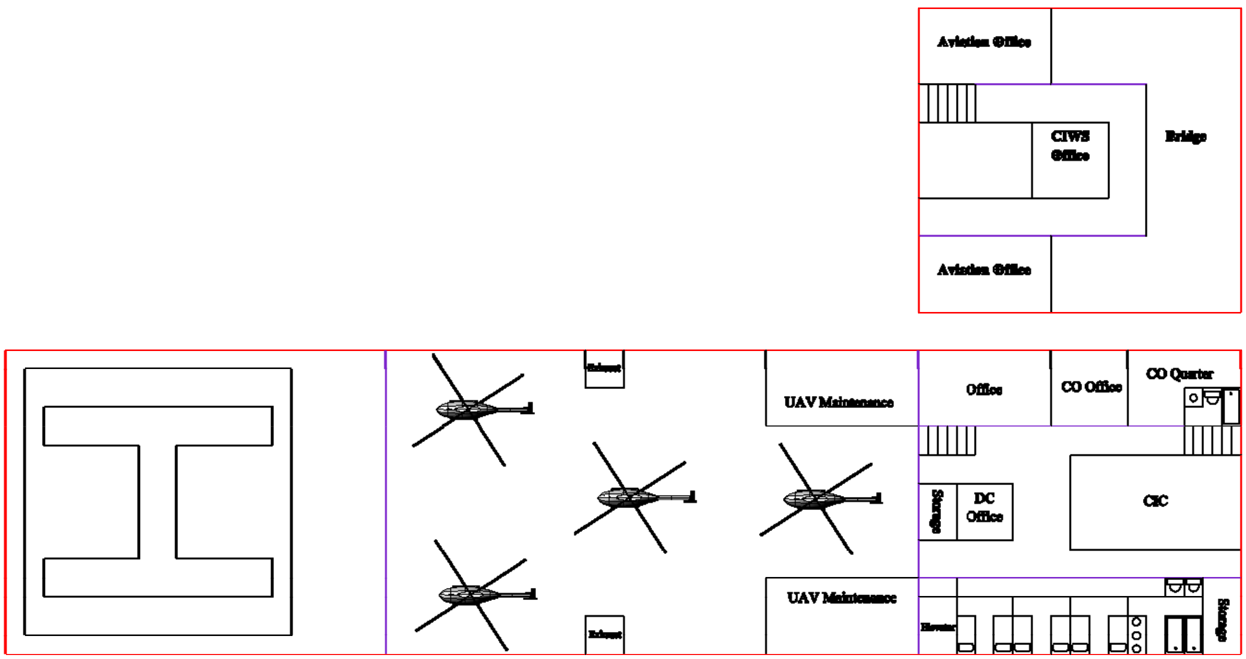
The LRS team has recommendations for further work on the Littoral Reconnaissance Ship project to include:

- Damaged Stability Calculations
- Seakeeping analysis
- Fuel cell technology by ONR
- Revise weights
- Structural design
- NAVAIR analysis of flight deck

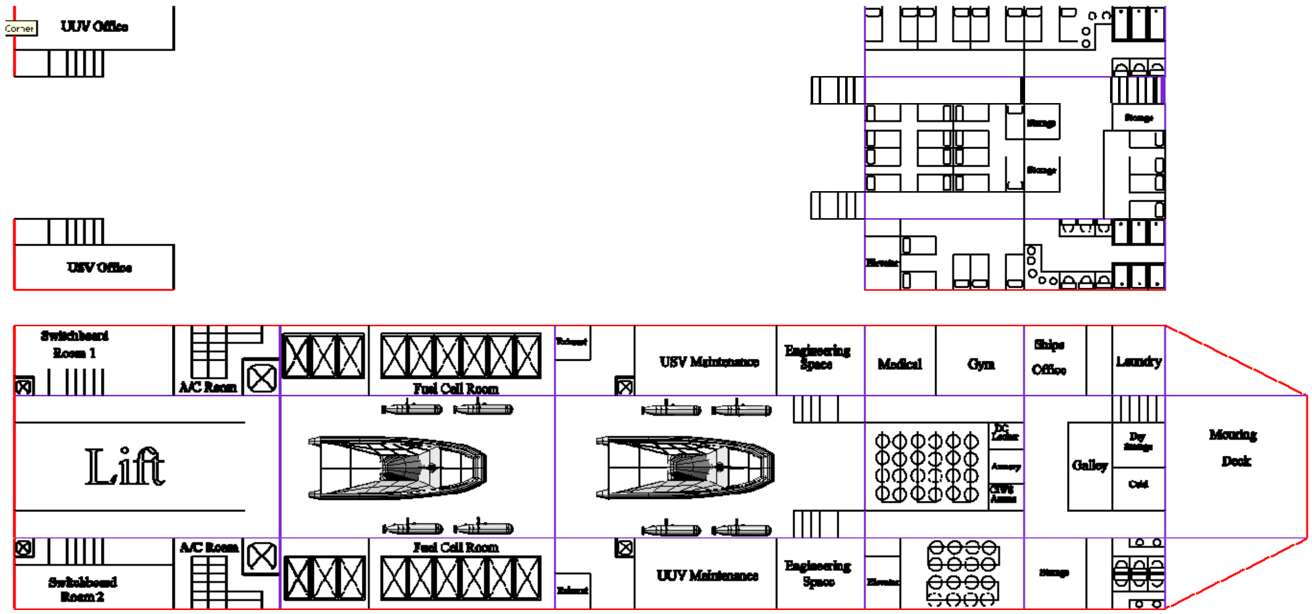
Appendix A: General Arrangements



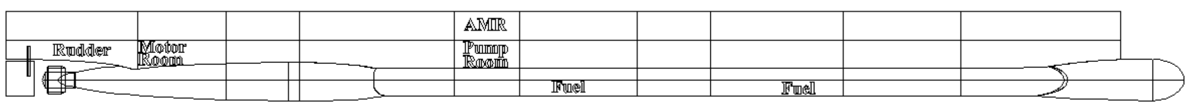
Inboard Profile



Plan View of 01 Level and Main Deck

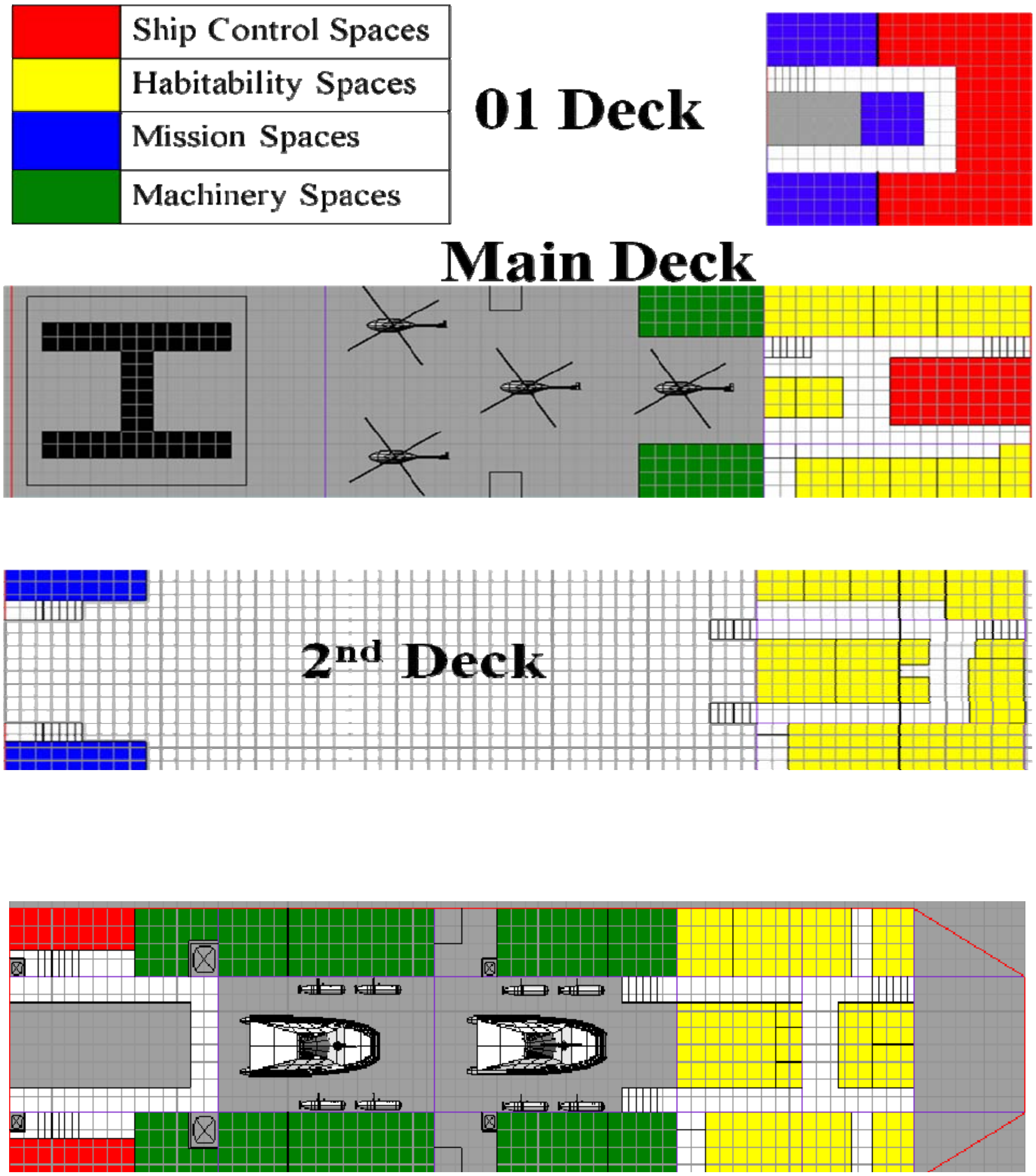


Plan View of 2nd Deck and 3rd Deck

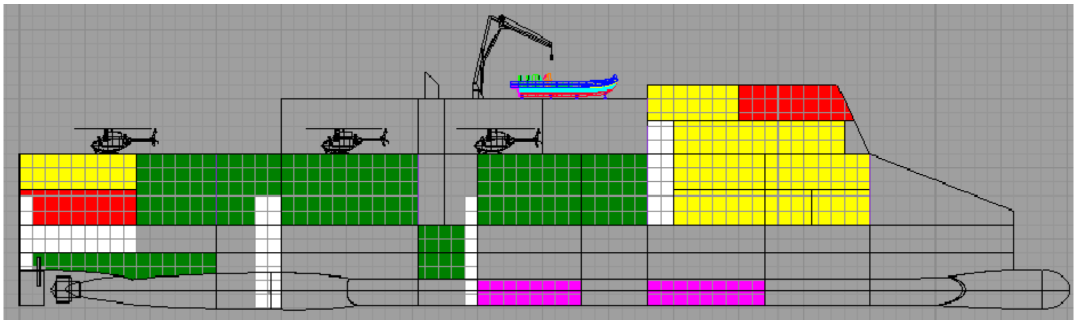


Inboard Profile

Appendix B: Functional Arrangement of Spaces

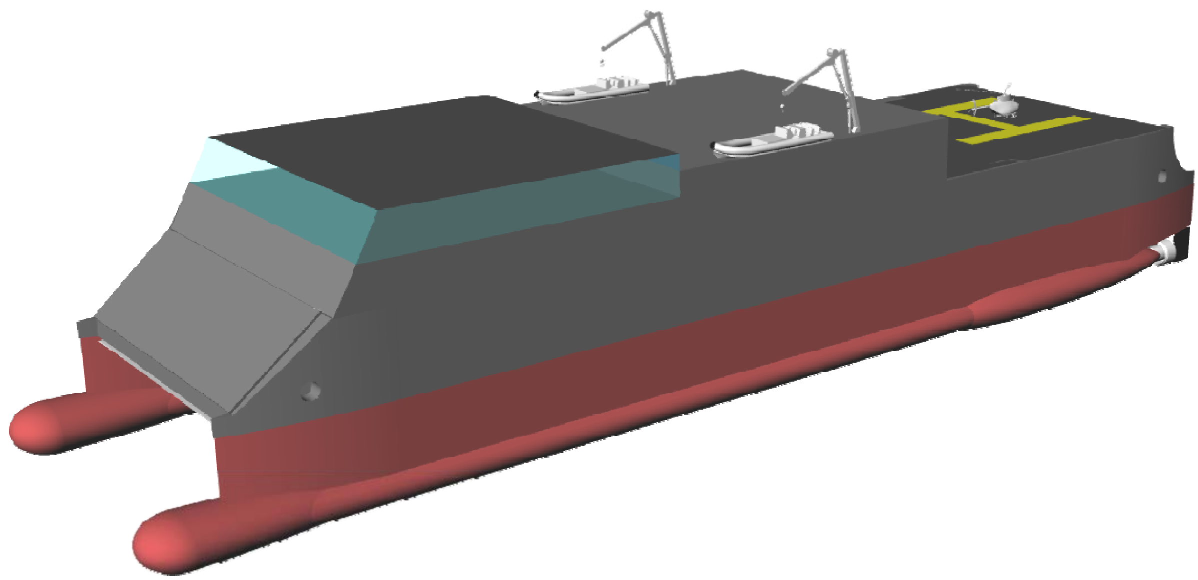


3rd Deck

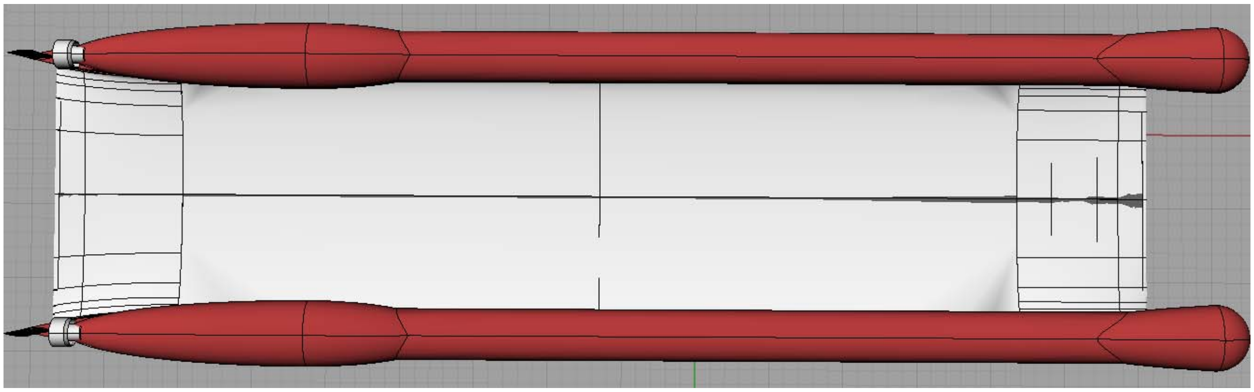


Profile View

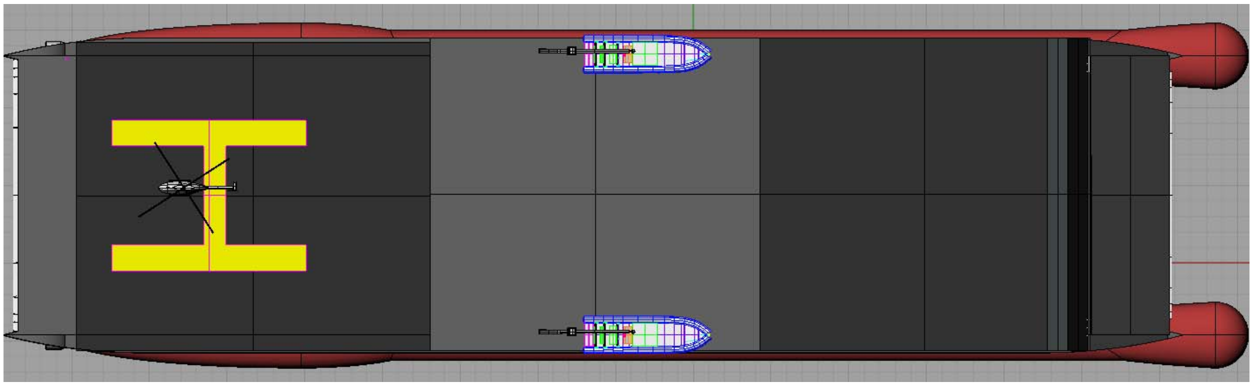
Appendix B: 3-Dimensional Views



Perspective View



Underside View



Topside View

Appendix C: Initial Design Brief

Littoral Reconnaissance Ship

Introduction

1. Modern unmanned and autonomous vehicles in the above water and underwater battle space provide unique capabilities for long range, short duration, reconnaissance in the littoral environment. However the limited persistency of these vehicles requires a ground or sea based facility to provide maintenance, logistics and operational control.

2. A Littoral Reconnaissance Ship shall be developed to provide the host ship for a range of Unmanned Aerial, Surface and Sub-Surface Vehicles.

Aim

3. To develop a small Littoral Reconnaissance Ship based on the HSSL SWATH hull form to allow persistence reconnaissance operations to occur at a geographic location away from the main Sea Shield and Sea Strike forces.

Ship Design Requirements

4. The vessel shall be capable of independent intra-theatre operations, a 1000Nm away from the support provided by an intermediate support base.

5. The vessel, each day, shall provide reconnaissance using unmanned vehicles in the following domains:
   - Above Water: 12 hours
   - Surface: 6 hours
   - Subsurface: 6 hours

6. Each vehicle shall be operated and maintained onboard the vessel, with dedicated refueling, mission management and maintenance facilities with launching equipment as appropriate.

7. The vessel shall operate in a sprint and drift manner, traversing between reconnaissance locations at speed, and then loitering at low speed while operating the unmanned vessels.

8. The vessel shall be capable of defending itself against attacks by hostile patrol craft.

Areas Of Technology Exploration

9. The following areas should be focused upon.

10. The ship design implications of embarking, supporting and autonomously operating the unmanned vessels.

11. Minimization of cost and size of the Littoral Reconnaissance Ship.

12. Use of the HSSL SWATH form in lightweight, high performance hull designs. Seakeeping, Stability, Resistance and Propulsion of the HSSL hull form.

Constraints

13. Only unmanned systems currently under development shall be considered.

14. A Pump jet propulsor shall be used.

15. Manning shall be minimized.

Approach

16. The team will review requirements and then brainstorm potential ideas.

17. Suitable ideas shall be assessed for architectural impact and technical feasibility.

18. The competing ideas shall be reduced to a preferred concept using a decision making process.

19. A ship design synthesis tool shall be developed.

20. A complete ship synthesis shall be undertaken. A balanced ship design shall result with performance analysis and a general arrangement developed.

21. The implications of any new technology or operational issues shall be noted.

Deliverables

22. All work will be documented in a CISD Project Technical Report. The final report and presentation shall be suitable for unclassified, public release.

23. During the first 2 weeks the team will produce a team project plan of actions, assignments and milestones. During the project this plan shall be maintained.

24. The team will develop and give informal intermediate presentations and a final project presentation.

25. The resulting ship design shall be detailed including a single sheet summary of characteristics, a comprehensive SWBS breakdown, a hull form body plan and a full general arrangement drawing.

26. The team will be encouraged to produce a technical paper from the final report that would be published at a professional society conference in the future.

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